CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-195

# GROUND CRACKS IN WOLF AND TEMECULA VALLEYS, RIVERSIDE COUNTY

BY

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## INTRODUCTION

The Elsinore fault zone in southern Riverside County was previously evaluated in FER-76 and supplements No. 1 and No. 2 (Saul, 1979) (Figure 1). At that time, the Wildomar fault and the southeasternmost segment of the Wolf Valley fault were included within Alquist-Priolo Special Studies Zones. The Willard fault and the northwestern segment of the Wolf Valley fault were judged to be not sufficiently active or well defined for inclusion within a Special Studies Zone (Hart, 1985).

Beginning in August 1987, ground cracks have developed in three housing tracts in the Pechanga quadrangle near the northwestern trace of the Wolf Valley fault as mapped by Kennedy (1977) (Figure 2). Other cracks have formed approximately along the same trend several miles to the northwest in Temecula and in the Rancho California business park (in the Temecula and Murrieta Quadrangles) (Figure 2). This cracking and the possibility of faulting in this rapidly developing area has caused much concern among developers, planners and others in the area. The ground cracks have triggered a number of geologic investigations, two of which have indicated a relationship between the cracks and pre-existing faults. Riverside County has asked CDMG to evaluate the cracks and associated faults.

The purpose of this report is to evaluate the ground cracks to determine if they represent a fault rupture hazard. This report includes an evaluation of data that have become available because of geologic investigations of the ground cracking, field observations of the ground cracks in 1988, and evaluation of the Wolf Valley and Willard fault zones in terms of recent faulting. A secondary purpose of this report was to evaluate recently available data on the Wildomar fault in those quadrangles where revised Alquist-Priolo Special Studies Zones maps might be issued.

## SUMMARY OF AVAILABLE DATA

The first ground cracks formed in 1987 in Wolf Valley, a 1 mile wide flat-floored valley at the southeastern end of the Elsinore Trough. As shown on Figure 2, Wolf Valley is bounded on the west by the Willard fault, at the base of the Santa Ana Mountains, and on the east by the Wildomar fault and an area of low hills (Kennedy, 1977). The floor of the valley is covered by Holocene alluvium of Pechanga Creek except for isolated hills of late Pleistocene Pauba Formation. At the south end of Wolf Valley, movement on the Elsinore fault zone steps from the Wildomar fault to the Wolf Valley fault. South of Wolf Valley, the Wolf Valley fault is the main strand of the zone. Within Wolf Valley, Kennedy (1977) proposed that Holocene offset had occurred on the Wolf Valley fault. Any evidence for Holocene movement on the Wildomar fault is obscured by "modern" alluvium (Kennedy, 1977).

The most abundant evidence for faulting is preserved in exposures of the Pauba Formation, an alluvial unit of late Pleistocene age. The Pauba Formation overlies a unit containing equivalents of the 0.7 m.y. old Bishop Ash (Kennedy, 1977). Kennedy shows the Pauba Formation to be overlain by terrace deposits, older alluvium, and Holocene alluvium. Consultants in the Temecula area generally distinguish only Pauba Formation and alluvium. It is not clear whether various consultants recognize older alluvium and group it with Holocene alluvium; do not recognize older alluvium and group it with similar-appearing Pauba Formation or do not map older alluvium because it is not present.

Wolf Valley cracks

Ground cracks were first noticed on August 23, 1987 across one recently completed housing tract and two other tracts under construction (Leighton and Associates, 1987a). These cracks parallel the Wolf Valley fault for part of their length, but diverge both to the north and south. The cracks were dominantly tensional with as much as 3/4" extension and 1/2" of vertical displacement, down to the east (GeoWest, 1987). The cracks formed a continuous, narrow zone of left-stepping en-echelon cracks, and some right stepping cracks in a sinuous zone trending approximately N20°W for approximately 3,500 feet (Figure 3).

Upon discovery of the ground cracks, the geotechnical consultants for the developers, GeoWest, and Leighton and Associates, immediately began investigations of the cracking. These investigations involved mapping of the cracks, excavation of fifteen backhoe trenches across the zone of cracking, and a review of the ground water levels and pumping activity in Wolf Valley. GeoWest (1987) and Leighton and Associates (1987a) found that in fourteen of the trenches the ground cracks occurred in a narrow zone within 20 feet of a pre-existing fault which cuts late Quaternary Pauba Formation and locally offsets latest Pleistocene or Holocene alluvium (Figure 3). One trench across the ground cracks (NF on Figure 3) did not encounter a fault in young alluvium. In the area studied by GeoWest (1987) (Figure 2), the fault varied in strike from N25°W to N42°W and in dip from 40 to 55 degrees to the northeast. The fault was characterized by a clay gouge zone or zones up to 18 inches thick which locally contained mullion structures indicating nearly horizontal movement. A trench log by Leighton and Associates (1987a), illustrating offset of alluvium, is shown as Figure 4. Carbon-14 dating of detrital charcoal from the alluvium by Leighton and Associates indicates that the alluvium is of Holocene age, but a precise date was not given (D. Lyerla, Richmond American Inc., personal communication, 1988).

Both GeoWest (1987) and Leighton and Associates (1987a) concluded that the ground cracking was due to long term subsidence caused by groundwater withdrawal. A first-order leveling survey by Riverside County showed that 2 to 2 1/2 inches of settlement occurred in central Wolf Valley between 1981 and 1987. Geowest and Leighton and Associates observed that pumping of Well 211 (Figure 3) by the Rancho California Water District since 1967 could have caused subsidence of the entire Wolf Valley. Pumping of Well 122 (Figure 3) beginning on August 17, 1987 could have increased the subsidence in the area near that well, causing cracks to open along the fault, a groundwater barrier (GeoWest, 1987; Leighton and Associates, 1987a). No information beyond that contained in the reports by GeoWest and Leighton and Associates was available from the Rancho California Water District due to pending litigation.

## Wolf Valley fault

The Wolf Valley fault was mapped by Kennedy (1977) based on "aligned hills and swales in cultivated farm lands" in Wolf Valley and closed depressions and linear topography south of Pechanga Creek. Holocene offset (presumably right lateral) was suggested based on tilted and dissected Holocene alluvium at Pechanga Creek and a groundwater barrier in central Wolf Valley (Kennedy, 1977). Saul (1979) evaluated the Wolf Valley fault for zoning under the Alquist-Priolo Special Studies Zones Act and determined that the fault was not well-defined northwest of Pechanga Creek. Subsequent investigations of the ground cracks (GeoWest, 1987; Leighton and Associates, 1987) also included trenches across the Wolf Valley fault of Kennedy (Figure 3). South of the zone of ground cracks, a fault offsetting Pauba Formation was found in one trench, but no faults were found in another. Where the Wolf Valley fault coincides with the ground cracks, evidence for Holocene (pre-cracking) offset was found in several trenches (see above). One trench across the Wolf Valley fault northwest of the ground cracks also showed the base of the Holocene alluvium to be offset 4 feet, down to the east.

## Rancho California cracks

After the Wolf Valley cracks had formed, other ground cracks were noted extending northwest from Temecula across Rancho California Road and through the Rancho California business park (Figure 5). These cracks are not coincident with any previously mapped fault but are roughly parallel to the Willard fault as mapped by Kennedy (1977) to the southwest (Fig. 2). No detailed studies of these cracks have been generally completed in this area, although they have been generally mapped by the County of Riverside (1988) and a study is underway by Schaefer Dixon and Associates.

Timing of the cracking is difficult to determine. Cracks were noticed following the November 23 and 24, 1987 Superstition Hills earthquakes, leading to some claims that they were caused by those earthquakes (reported by T. Rockwell, personal communication 1988). At one location, cracks were noticed following the October 1, Whittier Narrows earthquake, leading to similar claims (reported by R. Shlemon, personal communication, 1988). It is unclear if any cracks existed or were noticed before those earthquakes.

## Willard Fault

The Willard fault is a major strand of the Elsinore fault zone from Lake Elsinore south to Wolf Valley. Kennedy describes this fault as a zone of "northwest-striking, east-dipping, high-angle normal faults". Kennedy suggests that the granitic basement rocks are offset over 1000 m, down to the east, across the Willard fault zone. "Faulted Quaternary age sediments and a youthful topographic expression suggest a moderately young age for this part of the zone" (in the Temecula area) (Kennedy, 1977).

Detailed mapping and trenching has located the Willard fault in two areas near Temecula (Localities 7 and 8, Figure 2). At locality 7, Schaefer Dixon Associates (1987) found that the Willard fault offset Pauba Formation by at least 18 feet but that Holocene alluvium was not offset. At locality 8, Schaefer Dixon Associates (1988) found offsets in bedrock along a trace of the Willard fault. Holocene alluvium overlying this fault was not offset.

Wildomar fault

The Wildomar fault is the main strand of the Elsinore fault from Wolf Valley northward to Lake Elsinore. It is clearly an active fault with abundant geomorphic evidence of right-lateral Holocene activity (Kennedy, 1977; Saul, 1979). Horizontal slip-rate estimates have ranged as high as 7 mm/yr (Kennedy, 1977).

Detailed studies of the Wildomar fault have been conducted in accordance with the Alquist-Priolo Special Studies Zone Act at many sites in the Murrietta, Temecula and Pechanga Quadrangles. Figure 2 shows selected areas where the fault has been trenched and verified. Studies by Pioneer Consultants (1980), and Schaefer Dixon Associates (1987a), at locality 1, Figure 2, Leighton and Associates (1987) at locality 2, Figure 2, and Eberhard-Axten and Associates at locality 3, Figure 2, have verified the location of the Wildomar fault within the Alquist-Priolo Special Studies Zone on the Murrieta and Temecula quadrangles.

In the Pechanga quadrangle, the Wildomar fault has less distinct geomorphic expression but faults have been found at several locations. On the north side of Temecula Creek in Pauba Valley, Pioneer Consultants (1979) found a vertical offset of less than one foot, down to the northeast, within the floodplain deposits of Temecula Creek (locality 4, Figure 2). This fault was found at the same location as the trace mapped by Kennedy (1977) and Saul (1979). South of Temecula Creek two adjoining sites have been investigated by Pioneer Consultants (1980), Earth Research Associates Inc. (1987) and Pacific Soils Engineering (1987). Pacific Soils Engineering investigated the property along and west of the Wildomar fault from Temecula Creek to the south end of Wolf Valley. They mapped the area and logged trenches across suspected faults. Their trench 2 (locality 5, Figure 2) was excavated 10 to 15 feet deep completely across the Alquist-Priolo Special Studies Zone drawn around the Wildomar fault as mapped by Saul, no evidence of faulting was reported. However, a coarse channel deposit between 500 and 550 feet from the east end of the trench may be a late Holocene deposit along a linear drainage. Such a linear feature could have caused the tonal contrasts mapped by Saul. Pacific Soils Engineering observed faults in the Pauba Formation in several trenches along the edge of the hills east and southeast of locality 5.

The adjoining property, including the low hills east of Wolf Valley and part of southern Wolf Valley, was investigated by Pioneer Consultants (1980) and Earth Research Associates, Inc., (1987). Pioneer Consultants found evidence of faulting in two trenches across the Wildomar fault as mapped by Saul (1979) (locality 6, Figure 2). In trench 1 Pioneer Consultants show a fault which cuts lower alluvial units. In trench 2 the other exposure of this fault is questioned: They note that the "apparent normal offset" "May just be (a depositional) contact".

Earth Research Associates (1987) excavated and logged eight trenches near the trace of the Wildomar fault on the same property studied by Pioneer Consultants. Two trenches in the southern end of Wolf Valley cross the trace of the Wildomar fault as mapped by Saul (1979) near the trenches logged by Pioneer Consultants (1980). Unfortunately the logs of all the trenches are drawn with an assumed horizontal ground surface, are vertically exagerated two times, and appear to be somewhat schematic. The distortion in the way the logs are drawn, as well as the lack of detail, make it difficult to evaluate the data gathered by trenching. Earth Research Associates observed no faults in alluvium but do describe faults in the Pauba Formation along the edge of the hills. Their trench TT-9 excavated adjacent to trench 1 of Pioneer showed no faults. The log of their trench TT-7, excavated adjacent to trench 2 of Pioneer, appears to show an irregular, near-vertical boundary at the same location as the questionable fault logged by Pioneer. Earth Research Associates interpret this to be a depositional contact. Both Pacific Soils Engineering and Earth Research Associates show minor faults cutting the Pauba Formation along the edge of the hills. None of these trenches show evidence of Holocene faulting.

## INTERPRETATION OF AERIAL PHOTOS AND FIELD INVESTIGATION

### Wolf Valley cracks and Wolf Valley fault

Geomorphic features suggestive of recent faulting in the Wolf Valley area are shown on Figure 3. This geomorphology was plotted from aerial photographs taken by Fairchild Aerial Surveys in 1939, the U.S. Department of Agriculture in 1953 and the U.S. Geological Survey in 1967. Ground cracks were mapped January 22, 1987 and February 7, and 22, and June 22-23, 1988, the June dates in the company of E.W. Hart.

The most prominent geomorphic feature in the area is a northeast-facing scarp up to 50 feet high in western Wolf Valley. Other northeast and southwest facing scarps occur along the same trend to the southeast. These geomorphic features were part of the basis for the trace of the Wolf Valley fault drawn by Kennedy (1977). Other geomorphic features suggestive of recent faulting include a low east-facing scarp and tonal lineament which trends northerly across the trace of the Wolf Valley fault and a sharp, linear ridge and northeast-facing scarp on the Pechanga Indian Reservation south of the Wolf Valley fault. These features are all nearly parallel to the channel of Pechanga Creek and could have been formed or at least modified by stream erosion.

The ground cracks formed in 1987 largely coincide with the highest scarp. To the north the cracking diverges from the scarp along a broad tonal lineament. A closed depression is shown along this trend on a map prepared by the Riverside County Flood Control District.

Along the most prominent scarp, the ground cracks trend across the face of the scarp from the base at the north to near the top at the south (Figure 3). The cracks then trend southerly along the low east-facing scarp, away from the Wolf Valley fault mapped by Kennedy (1977). Where the east-facing scarp dies out at its south end, the ground cracks return to a southeasterly trend to follow an indistinct series of swales. Other geomorphic features to the southeast are not followed by ground cracking.

Geomorphic features suggestive of faulting were field checked on February 22 and June 3, 1988. The geomorphic features in the areas where ground cracking was observed have been largely obscured by grading. Features to the south have been somewhat obscured by plowing but are relatively distinct. Field observations are shown on Figure 3.

The zone of ground cracking in Wolf Valley was inspected on January 22, February 7, and June 3, 1988. Most of the ground cracks had been eroded or filled when observed, but partially filled ground cracks and aligned sinkholes could be traced across both of the partially developed tracts and onto an adjacent tract. On June 3, 1988 fresh cracks were observed locally (Figure 3). On the developed tract, cracks cross Calvado Court and several adjacent residential lots and have damaged driveways, a garage slab and houses. Degraded cracks and sinkholes were observed in unpaved areas along this trend. At Calvado Court the crack showed 4 mm of extension in asphalt on January 22, 1988.

## Rancho California cracks and Willard fault

The Rancho California cracks were observed in the field on January 22, February 7 and 22, and June 2, 1988. These cracks formed along a nearly linear zone for approximately 3 km northeast from Temecula (Figure 5). The southeastern segment of this zone of ground cracking was mapped by Riverside County geologists along the west side of Valdez Avenue on both sides of Baldaray Circle (Riverside County, 1988). This zone consists of separation between the concrete gutter and the asphalt paving and two to three inches of settlement of the concrete gutter where it crosses Baldaray Circle.

A second segment begins approximately 1,000 feet to the northwest where cracks cross Rancho California Road (Figure 5). These cracks form an orthogonal pattern extending diagonally across the street, cracks parallel and perpendicular to the street surround a manhole and appear to be forming due to settlement around a buried vault and pipelines.

The third segment of cracks extends north from Single Oak Drive in a narrow, linear zone with some left-stepping en-echelon segments across a compacted fill building pad. When observed these cracks had been degraded and locally enlarged by piping and collapse, but maximum extension across the cracks appeared to be 2 to 3 cm. No vertical offset was observed. These cracks die out as they approach the northern end of Business Park Drive.

Another crack-segment begins on the south side of Business Park Drive at its northern end and extends at N20°W across the street, through the large tilt-up building on the north side of Business Park Drive and about 100 feet to the northwest. Up to 10 cm of vertical, down to the east, displacement of the curbs of Business Park Drive was measured on June 2, 1988. Cracks in the floor slab of the building were up to 2 cm wide and had up to 1 cm of vertical offset with the northeast side down when they were observed on January 22, 1988. Concrete curbs at the northern corner of this building had been offset 12 mm extensionally, 20 mm vertically (down to the east), and 21 mm right-laterally on June 2, 1988. Cracks form a continous en echelon zone in the asphalt parking lot behind the building but could not be traced across the unpaved area to the northwest. Along the same trend to the northwest, cracks on a 4-5 cm high monoclinal warp in an asphalt roadway and a sinkhole with internal drainage observed on June 2, 1988 on the sewage treatment plant property may indicate subsurface continuity with the northern segment of cracks.

The northern segment of cracks forms a narrow zone across Avenida Alvarado, through an industrial building, across Rio Nedo Rd., through a building supply yard on the northwest side of Rio Nedo Rd and for over 300 m into a plowed field. On the north side of Rio Nedo Rd., extensional cracks along joints in a concrete driveway and parking area were 7 to 8 mm wide on June 2, 1988. The cracks had been enlarged by piping and erosion where they cross unpaved areas. At the farthest extent of the cracking the zone bends to a northerly trend before dying out.

Three trenches have been excavated across the Rancho California cracks by Schaefer Dixon and Associates (Trenches 1, 2 and 3, Figure 5). The trenches were excavated during the first week of February, 1988 and observed by this writer on February 7 and 22. On February 7 the trenches were just completed, but the walls had not been cleaned for logging. On February 22 logging was essentially complete and I was given a brief tour of the trenches by Dr. R.J. Shlemon. Trench 1 showed 6 to 8 feet of fill over a horizontally bedded sequence of mostly silty sands. A clay layer about 12 feet below the surface provided organic material that may be datable by 14 C methods. This clay layer overlies a layer of medium to coarse-grained loose sand. All of the sedimentary layers can be traced for the length of the trench but thicken to the east of the zone of ground cracks. The modern ground cracks coincide with existing sand-filled fractures where sand from the layer at the bottom of the trench have been injected up into the overlying layers. These sand-filled fractures, which Dr. Shlemon interprets to be liquefaction features, occur in a zone approximately 50 feet wide. No faults or vertical offsets have been observed on any of the sand filled fractures or on the modern ground cracks.

Trench 2 shows very similar stratigraphy and localization of cracks along sand-filled fractures. Trench 3 shows horizontal layering in the west half of the trench which is apparently truncated by a eastward dipping contact at the zone of ground cracking. The predominantly sandy layers on the west half of the trench contain granitic cobbles, which have weathered to grus. These sediments are interpreted by Dr. Shlemon to be of Pleistocene age, probably equivalent to the Pauba Fm. They are overlain by similar material which is crudely bedded and dips gently to the east. Shlemon interprets this material to be slopewash over an ancient channel margin or terrace edge. In the eastern half of the trench this slopewash is overlain by floodplain deposits of Murrieta Creek and artificial fill. The ground cracking appears to be localized by the difference in materials across this paleo-escarpment. No evidence of faulting was observed, although sand filled fractures were observed near the base of the paleo-escarpment. A 5" wide soil-filled fissure extending approximately 4 feet down from the ground surface (which Dr. Shlemon interprets to be a trench or other man-made feature) could have formed and filled due to ground cracking.

On 1939 and 1953 aerial photos, the area now occupied by the Rancho California Business Park was an area of open fields. A low, west facing scarp and a tonal lineament are approximately aligned with the northern segment of cracks but are south of those cracks. The northern ground cracks approximately follow a slight east facing scarp. Other ground cracks in the business park locally follow stream channels but do not coincide with geomorphology that is suggestive of faulting.

North of the business park area, a sinuous escarpment extends northwesterly from the zone of ground cracks (Figure 6b). This escarpment lies at the edge of the flood plain of Murrieta Creek. Low hills rise to the southwest. Kennedy (1977) interpreted this as the depositional contact between Pauba Formation and alluvium. The sinuous trace of the escarpment makes a fault origin seem unlikely.

Leighton and Associates excavated several trenches across the escarpment in June, 1988. These were field checked by this writer, accompanied by M. Bergman and D. Schwartzkopf of Leighton and Associates and T. Rockwell of San Diego State University, on June 27, 1988. These trenches clearly show that the escarpment is a fault scarp. At one point, adjacent to Trench 1 (Figure 6b), this scarp has a "free face" steeper than 50° over 1 meter high. Trench 1 shows that the surface soils have been offset down to the east about 1 meter on a plane that dips to the northeast at about 45°. A buried "A" horizon has been offset on the same plane approximately 3 meters. The greater offset of deeper, but probably Holocene layers implies multiple Holocene displacements. The fresh surface morphology implies that the latest of these occurred very recently, perhaps within the last few hundred years.

North of the area investigated by Leighton and Associates, a straight scarp extends to the northwest. Two tonal lineaments branch from the end of this scarp (Figure 6b). Fault-related geomorphic features were not found along this trend to the northwest.

## CONCLUSIONS

### Wolf Valley cracks and Wolf Valley fault

Ground cracks formed in Wolf Valley in 1987, possibly as a result of ground subsidence. The cracks formed along a previously existing fault which has a gouge zone up to 18 inches wide. Nearly horizontal mullions within the gouge zone probably indicate that the fault has a large component of strike slip movement (GeoWest, 1987). Offsets of Holocene alluvium down to the east clearly indicate that Holocene offsets prior to cracking have occurred and include a normal component.

This fault zone is mostly well defined by geomorphic features and appears to be part of the Wolf Valley fault zone of Kennedy (1977). Other geomorphic features suggestive of Holocene faulting exist to the southeast (Figure 3). These features do not suggest a single through-going strike-slip fault, but could be part of a complex right-step in the Elsinore fault zone between the Wildomar fault to the north and the Wolf Valley fault to the south. The discontinuous short faults within Wolf Valley may be part of a stepover between the Wildomar and Wolf Valley faults.

### Rancho California Cracks and Willard fault

The ground cracks north of Temecula formed three or four months after the Wolf Valley cracks and are similar to the Wolf Valley cracks in surface appearance. The cracks constitute a 3 km long, discontinuous, nearly linear zone (Figure 5). A single, somewhat sinuous crack was most common but left-stepping en echelon cracks were also observed. Most parts of the ground crack showed only extensional movement. Vertical offset was most prominent on the crack at the north end of Business Park Drive reaching a maximum of about 10 cm. Right lateral offset was also observed on parts of this crack segment.

The two crack segments at Rancho California Road and along Valdez Avenue do not have the same patterns of cracking as the northern cracks. Ground cracks in these two areas appear to be controlled by buried utility lines or structures. Settlement of fill around these structures could have caused these cracks.

The three crack segments north of Single Oak Drive resemble cracks that have formed due to subsidence over buried topography (Holzer, 1984). Trenching of these cracks did not reveal evidence of faulting but did suggest that buried topography is controlling the location of the ground cracking. This buried topography could be related to stream erosion or could be a fault scarp. On a smaller scale the ground cracks are localized by sand filled fractures which are probably liquefaction features. To the north of Business Park Drive, scarps and tonal features suggestive of recent faulting closely parallel the ground cracks (Figure 5).

Fault related geomorphic features also extend to the northwest from the zone of ground cracks (Figure 6b). The steepness of the scarp and the offset upper soil in trenches imply that the most recent event on this fault occurred in late Holocene time. Greater offset of deeper layers implies multiple Holocene events. Apparent normal offsets were observed in the trenches. The sinuosity of the trace implies that normal faulting is predominant along this fault, which may be a previously unmapped strand of the Willard fault zone. Other, previously mapped strands of the Willard fault have not been found to offset Holocene alluvium.

### Wildomar Fault

The Wildomar fault is a major right-lateral strand of the Elsinore fault zone. North of Temecula Creek it is well defined geomorphically and has been located in several trenching investigations (Figure 2). South of Temecula Creek the Wildomar fault is only generally defined by a linear hill front and definite evidence for Holocene movement has not been found.

The less well defined trace of the Wildomar fault in this area may reflect a decrease in activity as offset in the Elsinore fault zone is transferred to faults on the west side of Wolf Valley.

## RECOMMENDATIONS

The following features are recommended for zoning under the Alquist-Priolo Special Studies Zones Act. References cited on maps of the Murrieta, Temecula and Pechanga quadrangles should be Kennedy (1977), Saul (1979) and this FER.

### Wolf Valley Cracks and Wolf Valley fault

The ground cracks in Wolf Valley form a narrow, sinuous zone and have offset of the ground surface extensionally and vertically. Although the cracks may be caused by subsidence, they closely follow a pre-existing fault that locally offsets Holocene alluvium. The cracks and Holocene fault also locally follow the Wolf Valley fault of Kennedy. The ground cracks, and adjacent geomorphic features (Figure 6a) are sufficiently active and well defined and should be zoned. Other segments of the Wolf Valley fault are not well defined and are not recommended for zoning.

### Rancho California Cracks

The ground cracks north of Rancho California Road form a narrow, discontinuous linear zone and have displaced the ground surface extensionally, vertically and locally right-laterally. Although limited trenching across the cracks has not exposed a pre-existing fault, geomorphic features along and northwest from the ground cracks suggest that these cracks may follow a pre-existing fault for part of their length. The crack segments shown of figure 6b are recommended for zoning. The two southern crack segments (Figure 5) are not recommended for zoning. The sinuous, well-defined scarp northwest of the ground cracks show evidence of repeated faulting and is also recommended for zoning.

### Wildomar fault

Trenching studies have located the Wildomar fault within the Alquist-Priolo Special Studies Zone at localities 1, 2, 3 and 4. No changes are recommended for this segment of the fault. Trenches at localities 5 and 6 found no or only equivocal evidence for Holocene faulting, but late Holocene deposits may be obscuring the fault.

The Special Studies zone along the Wildomar fault from Temecula Creek to Pechanga Creek should be retained until further trenching of older deposits has either located the fault or clearly shows that early Holocene or late Pleistocene deposits are unfaulted.

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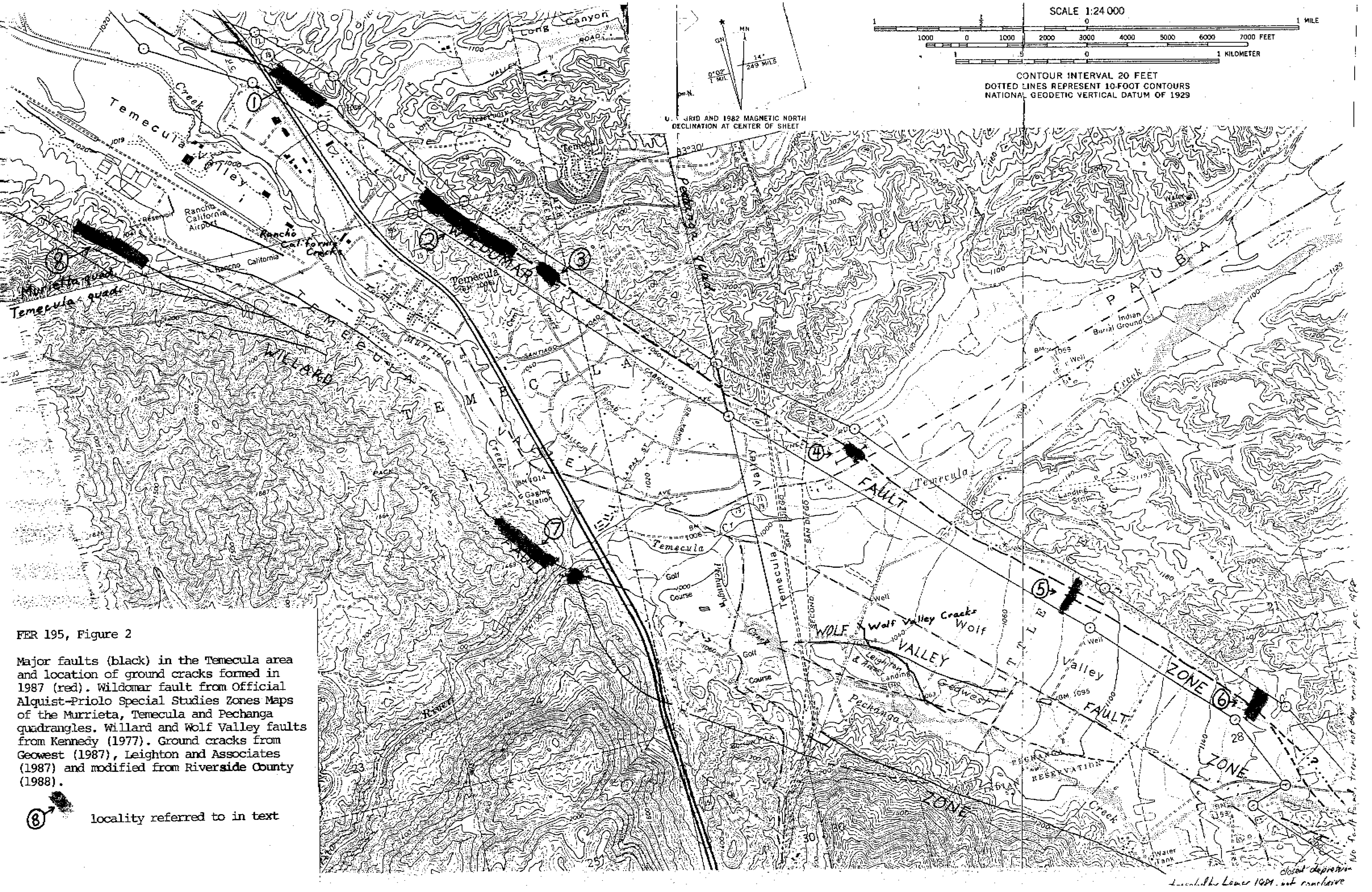


FER 195, Figure 2

Major faults (black) in the Temecula area and location of ground cracks formed in 1987 (red). Wildomar fault from Official Alquist-Priolo Special Studies Zones Maps of the Murrieta, Temecula and Pechanga quadrangles. Willard and Wolf Valley faults from Kennedy (1977). Ground cracks from Geowest (1987), Leighton and Associates (1987) and modified from Riverside County (1988).

8 locality referred to in text